DEEP-WELL INJECTION OF
INDUSTRIAL WASTES IN OHIO

by

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ABSTRACT

Deep-well injection has been used by Ohio industries as a method of waste disposal since 1967. Deep-well injection is today the preferred means of disposal by industries generating large volumes of liquid wastes. In 1984, Ohio's 15 operating deep-wells, located at seven sites, were injecting at a total monthly rate of 30 million gallons. The use of these injection wells has not resulted in a single known instance of pollution, but, the possibility of contamination to fresh water aquifers remains. The Mt. Simon Sandstone is the only formation that has been targeted to store waste. However, well failures have resulted in leakage into other zones. Because of the immediate and long term pollution potential of deep-well injection, this practice should be used sparingly.

ACKNOWLEDGMENTS

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INTRODUCTION

Industries in Ohio may employ four types of land disposal or treatment techniques to eliminate the wastes generated by their operations. Depending on the nature and volume of these wastes, industries may use surface impoundment, "landfarming", landfill, or deep-well injection. Deep-well injection, which was first used in Ohio in 1967, is today the preferred means of disposal by industries generating large volumes of wastes that cannot be feasibly treated by other methods. The use of these injection wells in Ohio has not resulted in a single known instance of pollution; in this aspect the wells have been a success. However, the potential for ground water contamination does exist and increases as greater volumes of wastes are injected into the subsurface environment. Deep-well injection as a permanent means of waste storage has inherent environmental risks resulting from the complex relationships that exist between well construction, operation, and the geologic characteristics of the well site. The application of deep-well injection with appreciable environmental risks has been demonstrated to some degree by practice and study, but, the extent that this method of disposal can be safely implemented has not been determined. Because of the immediate risks that deep-well injection poses to the environment, the uncertainty of its long term effects, and its use of a limited natural resource, it cannot be viewed as a solution to Ohio's industrial waste problem.

INJECTION WELLS IN OHIO

Before deep-well injection became a common practice in Ohio, many of the industries that now use this disposal method were indiscriminatly dumping their wastes into streams and rivers. It was not until water pollution became a widespread problem that industries, faced with impending federal legislation (such as The Water Pollution Control Act of 1972) began to explore safer means of disposal. For decades, brines associated with oil production had been successfully injected back into the formations from which they were extracted. Industries found this same technology feasible as a disposal method for their wastes. However, the hazardous nature of much of these wastes and the fact that these liquids were being introduced to the geologic formations, not replaced, required additional criteria for siting, construction, and operation of the wells.

A personal interview with Bob Carey of the Ohio Environmental Protection Agency indicates that the Ohio E.P.A. now reconizes 5 different classes of injection wells. The classifications of these wells are based on the type of injected liquid wastes. Class I injection wells are "wells injecting industrial wastes beneath the lowermost formation containing a source of drinking water." This classification at one time covered only hazardous wastes but now encompasses all industrial wastes. Class I wells are the wells commonly referred to as deep-wells. Classes II, III, and V handle wastes that range from oil field brines to surface storm runoff. Often these wells are nothing more than pits. Class IV wells are wells designated to handle radioactive wastes. No Class IV wells have been permitted in Ohio and none of the other wells have been known to inject radioactive wastes.

A personal interview with Thomas E. Crepeau of the Ohio E.P.A. revealed that there are presently 17 deep-wells in Ohio. Of these, 15 are in operation, 1 has been plugged, and 1 has been inactive for several years. There are also 2 deep-wells awaiting approval of their operating permits. All of these wells are located at the sites where the wastes are generated, except for a single site from which Chemical Waste Management operates six wells for use by many different industries. The locations of these wells and the facilities names are given in Figures 1 & 2.

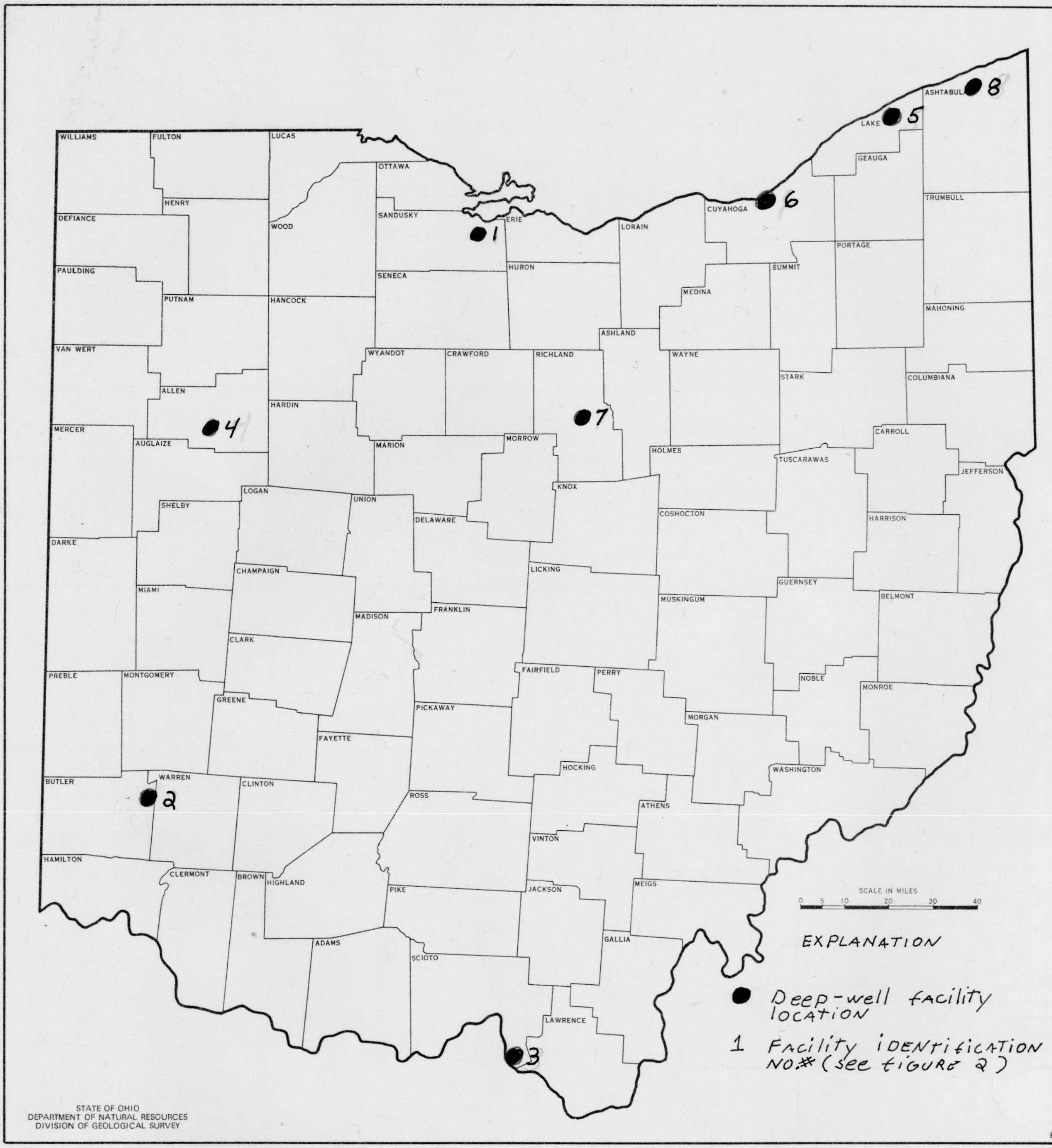

Figure 1. Locations of deep-well facilities.

Map No.	Facility name and location.	No. of wells	Hazardous waste	Description of waste
1	Chemical Waste Management (Ohio Liquid Disposal) Vickery, Ohio	6 in use ~~1 plugged~~	yes	Many types of wastes from many different industries.
2	Armco, Inc. Middletown, Ohio	2 in use	yes	Hydrochloric acid pickling liquors.
3	U.S.S. Chemicals Haverhill, Ohio	2 in use	yes	Acetone and other wastes from the manufacture of phenol.
4	SOHIO Chemicals (Vistron) Lima, Ohio	3 in use	yes	Ammonia, sulfate, cyanide, and acid waste from an acrilonitrile plant.
5	Calhio Chemicals Perry, Ohio	2 in use	no	Organic wastes from the manufacture of fungicides.
6	International Salt Cleveland	1 inactive	no	Brines pumped from their mines.
7	Empire- Reeves Mansfield, Ohio	1 plugged	yes	Sulfuric acid pickling liquors.
8	Reserve Environmental Ser. Ashtabula, Ohio	2 proposed	no	A neutralized acid brine.

Figure 2

The 17 deep-wells that have operated in Ohio have injected a variety of wastes, most of which are considered hazardous. The specific wastes injected at each site are described in Figure 2. A summary of what constitutes wastes as being hazardous, as defined by the Federal E.P.A., "are those wastes which pose a potential hazard to human health or to the emvironment." The hazardous materials list of the Federal E.P.A. contains over 250,000 entries. These wastes are subdivided into the following classes: flammable; corrosive; reactive; infectious; radioactive; and toxic, with additional criteria for testing to determine the hazardousness of each class. Waste generators are responsible for determining if their wastes are hazardous or not, and in so doing, the generators find out which regulations their wastes must comply with for transportation and treatment or disposal.

INJECTION WELL DESIGN

The ideal construction of a deep-well for injecting liquid waste into deep subsurface formations is shown in Figure 3. Although the wells in Ohio may vary from this model, it offers an accurate generalization of many of their standard features. A summary of the wells construction from Michael J. Clifford's _Feasibility of Deep-well Injection of Industrial Liquid Wastes in Ohio_, explains the model as follows. At the surface, a steel casing is cemented in place from ground level through the entire Permian fresh water zone and into an additional several hundred feet of the Pennsylvanian strata. This surface casing acts as an added sheild to protect the fresh water zone. From the surface through the surface casing and down to the Cambrian injection zone, a string of casing known as the "long string" is cemented into place. Through the "long string", the "injection string" is placed into the injection zone. The "injection string"

WELL DIAGRAM

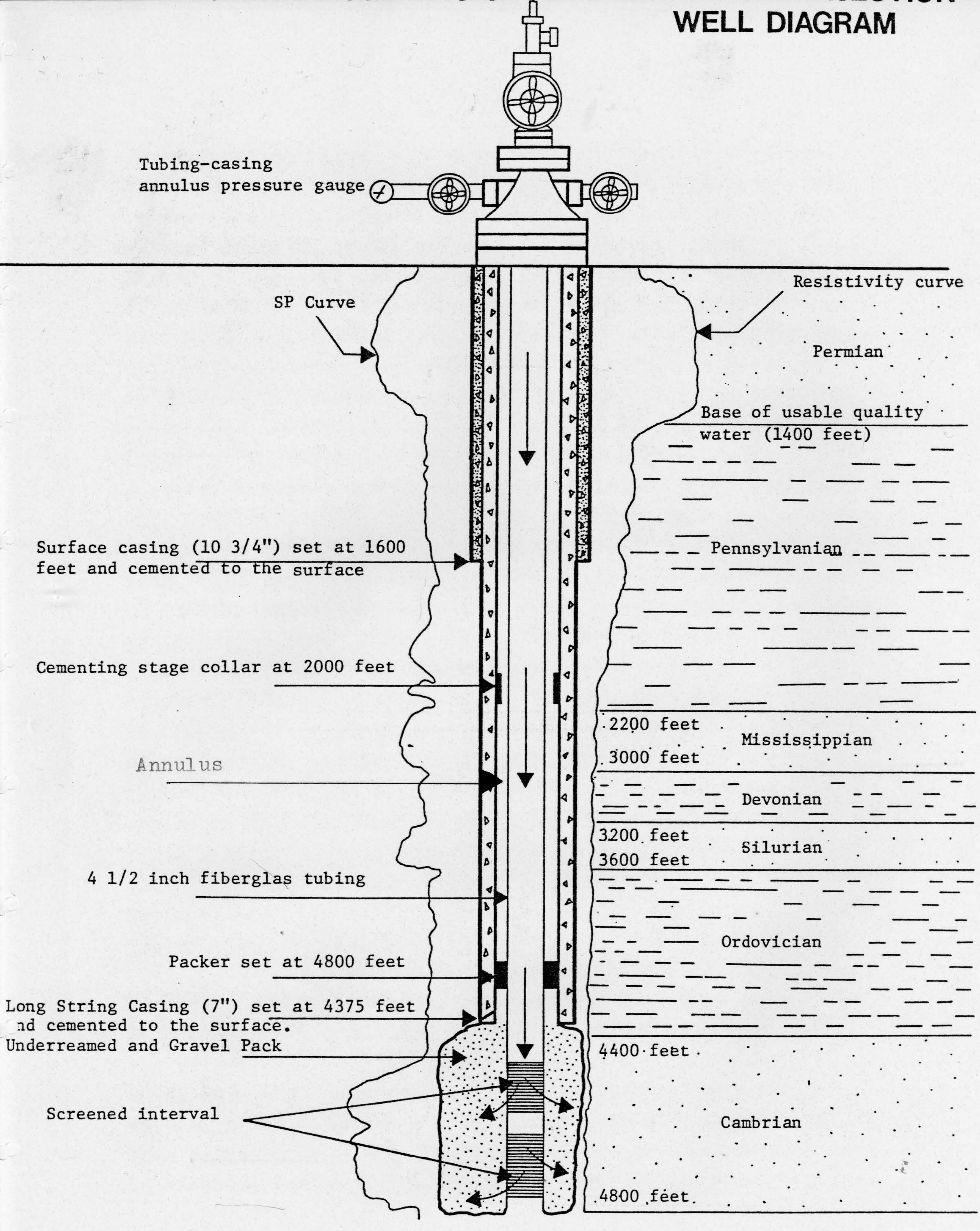

Figure 3. Well diagram.

is made of fiberglass or coated steel to resist corrosion. Also, the cement which is used is made with an acid resistant latex. The area between the "long string" and the "injection string" is known as the annulus.. This cavity, running the length of the well is sealed at the bottom by a packer and filled with an inert fluid whose pressure is maintained and monitored from the surface. If leaks develop in any of these casings, automatic shut off devices would be activated by by changes in pressures. Of course, any deviation from the ideal model would increase the risks of well failure and leakage. The pressures of a well that operates without the shut off divices must be carefully monitored by a competent well operater at all times. With injection rates sometimes as high as 166 gallons per minute for periods of months, a leak could inject large volumes of waste into untargeted zones.

The maximum pressures (and subsequently the maximum rates of injection) are limited by the break down pressure. The break down pressure is the average pressure for the state at which fracturing of the injected formation may occur. The conservative break down pressure of 0.75 psi per foot of well depth, has been established from fracture testing of several wells. The maximum injection pressure that a well may operate at is based on the following formula:

$$(d \times Bp) - (d \times Pg) = Mp$$

where

d = Depth of the well.
Bp = Break down pressure (0.75 psi/ ft).
Pg = Pressure gradient of the liquid waste.
Mp = Maximum surface injection pressure.

A maximum surface pressure of 750 psi is permissable for a well injecting a waste with a pressure gradient of 0.5 psi/ft into a formation 3,000 feet deep. These pressure limits must be strictly adhered to because the artificial fracturing that could occur from excessive pressure introduces several undesirable conditions.

THE MT. SIMON AS A STORAGE RESERVOIR

The only formation in Ohio that has been targeted to store industrial wastes, until recently, is the Mt. Simon Sandstone of Cambrian age. Clifford proposed the Mt. Simon's lack of valuable mineral deposits, its isolation from aquifers, and its ability to accept large volumes of fluid, make this formation a suitable storage reservoir. Although the volumes of wastes that this reservoir may hold is large, there is only a limited amount that can be stored safely.

Working with over eighty core samples, A. Janssens in Stratigraphy of The Cambrian and Lower Ordovician Rocks in Ohio, stated that the Mt. Simon consists of fine- to coarse-grained, poorly consolidated sandstone, that non-conformily overlies the Precambrian metamorphic and ingneous basement rocks. In several localities, the basal portion of the Mt. Simon grades downward into a conglomeratic sandstone. The sandstone is generaly poorly sorted with individual beds being well sorted. The cement is mostly silica with dolomite and hemitite present in places. Another major mineral constituent is microcline, which gives the Mt. Simon an abnormally high radiation level for a sandstone. Glauconite is also present, but only in traces.

The Mt. Simon Sandstone has not been found to contain any minerals of economic value. There have been no wells to produce hydrocarbons from the formation, and only a trace of gas was reported from one well. The natural brine fluid in the Mt. Simon has no commercial value.

The maximum concentration of dissolved solids in the brine fluid are found in the eastern portion of the state. The concentrations in the east are roughly 300,000 mg/l and about 2/3 less in the west. These high salinities indicate to some extent that the Mt. Simon is well confined and that its fluids are stagnant.

Janssens determined that the thickness of the Mt. Simon ranges regionally from 350 feet in the west to less than 100 feet in parts of central Ohio. The formation thickens again eastward through the state to 200 feet. The thickness of the Mt. Simon in a given locality is determined by its relief on top of the Precambrian basement rock. The basement structure known as the Cincinnati Arch rarely has dips exceeding 1 degree. This structure has an eastward steepening dip in central Ohio. In northwest Ohio it has a northwestward dip. The Mt. Simon Sandstone overlying this structure finally outcrops to the west at its type locality in Eau Claire, Wisconsin. An isopach map contouring the Mt. Simon's thickness is given in Figure 4. The depth to the top of the Mt. Simon is shown in Figure 5 and in generalized rock column of Ohio (Figure 6).

A major limitation on the regional extent that the Mt. Simon can be used for injection are from its limited permeability and porosity. Clifford estimated that for permeabilities to reach adequate levels for injection, porosity should exceed 11% for an average thickness of Mt. Simon Sandstone. Figure 7 illustrates the distribution of porosities with the injection potential regions superposed over them. The map indicates that the porosities and potential for injection decrease eastward as the depth to the Mt. Simon increases.

CAPACITY OF THE MT.SIMON

In 1972 there were 5 deep-wells injecting industrial wastes into the Mt. Simon. Clifford showed that these wells were handling about 0.03% of all of Ohio's industrial wastes at a total monthly rate of 21 million gallons. The 15 wells that were operating in 1984 were injecting at a total monthly

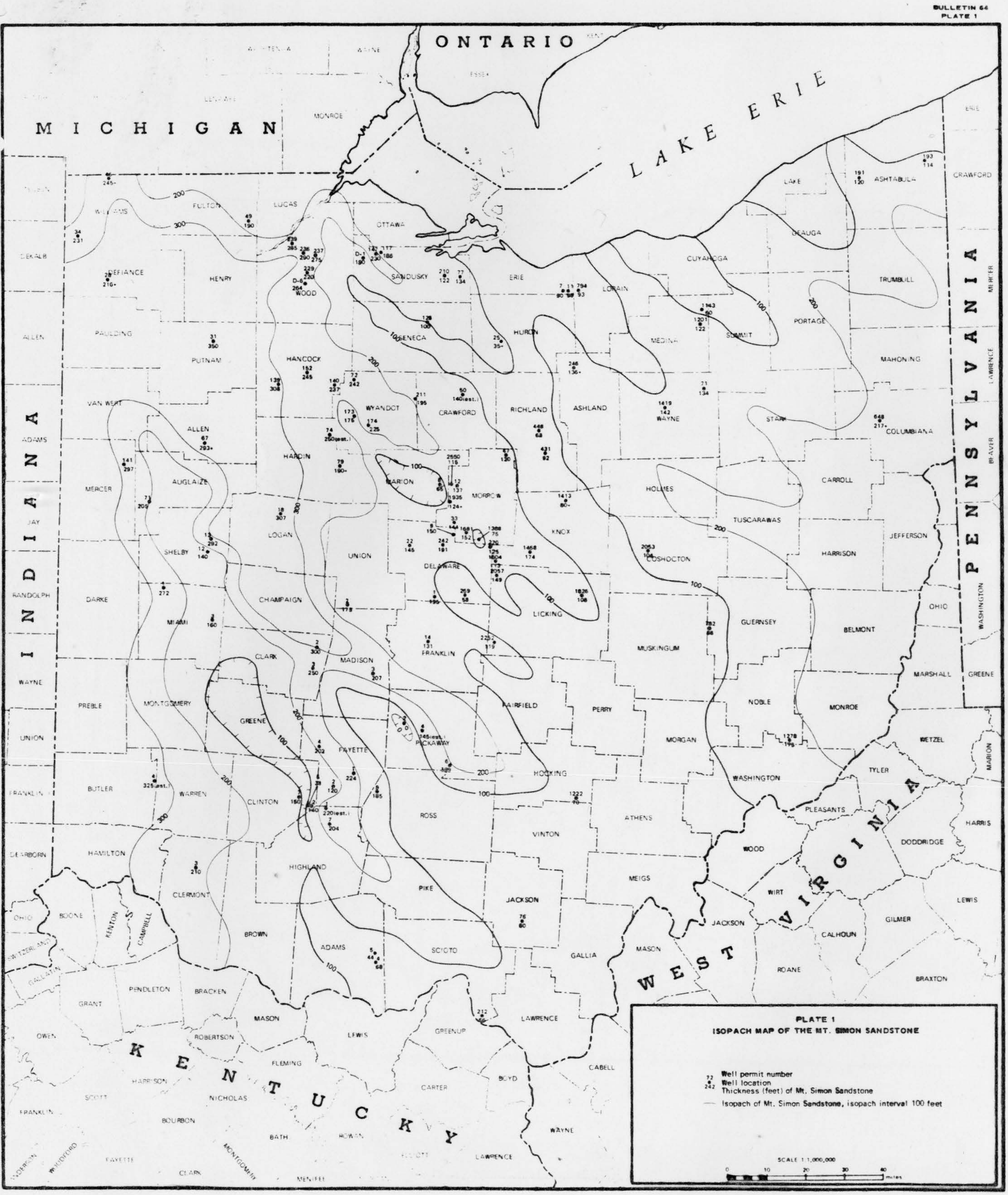

Figure 4. Isopach map of the Mt. Simon.

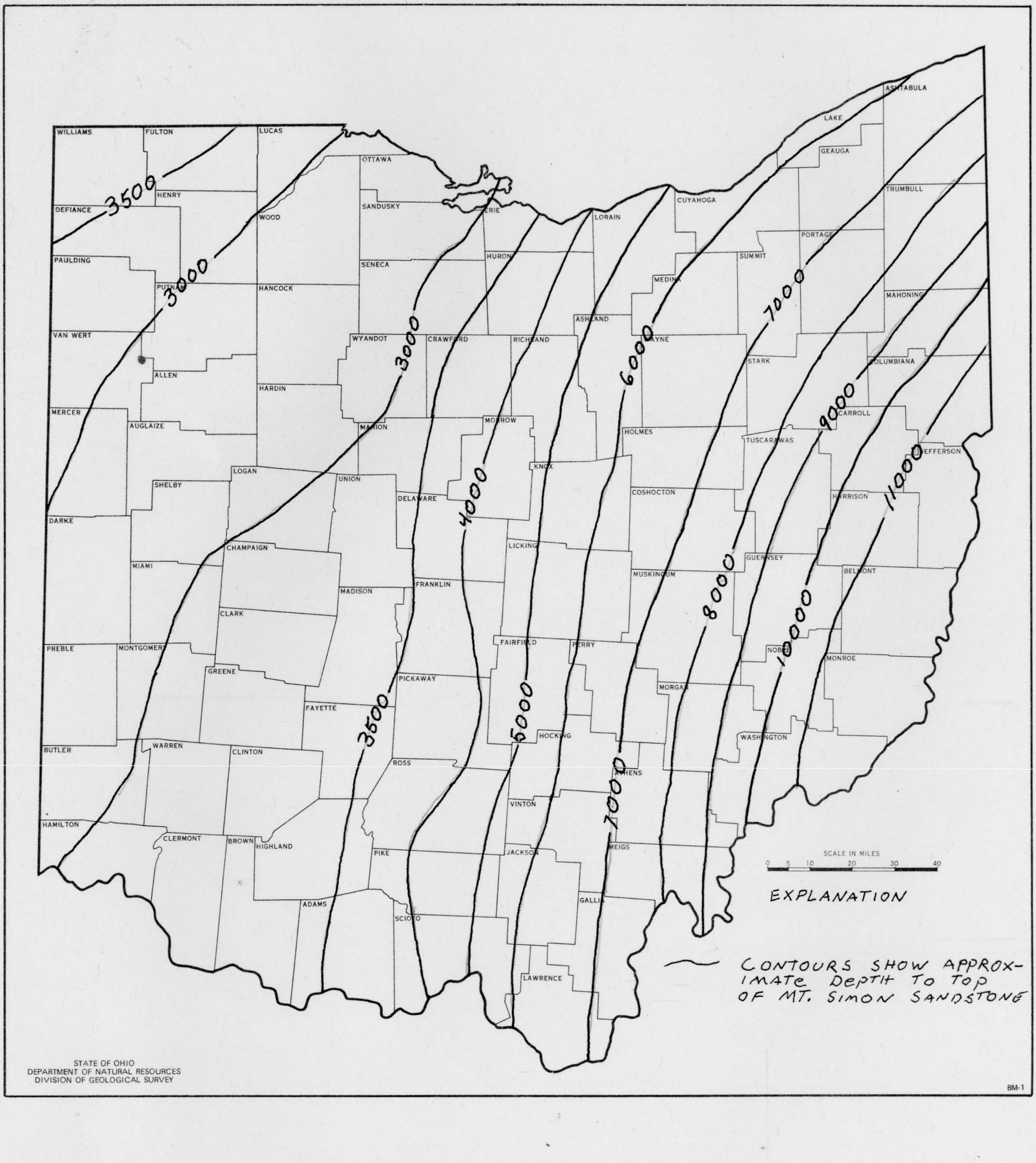

Figure 5. Depth to top of Mt. Simon in feet below land surface, ignoring topography.

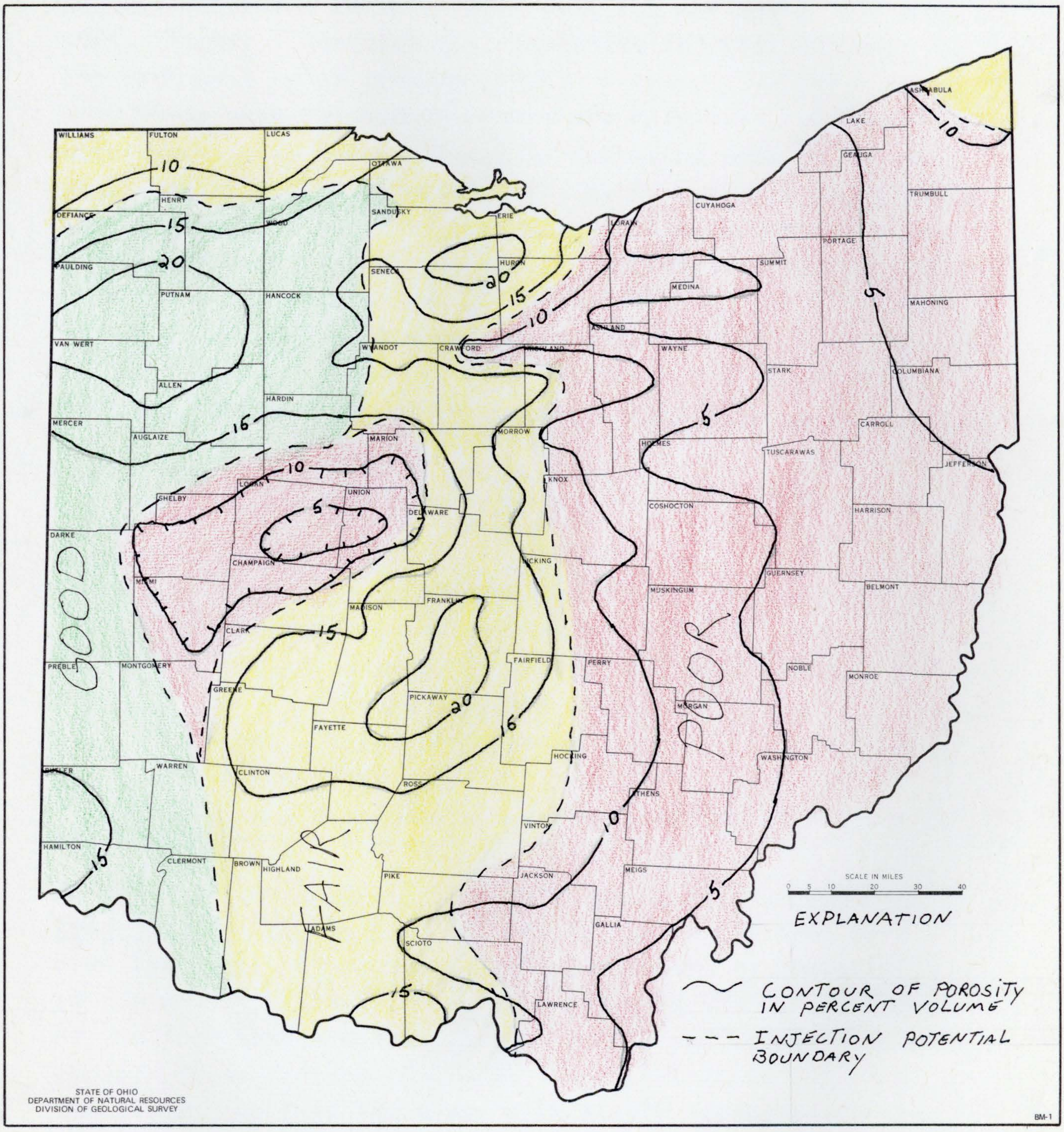

Figure 7. Porosity of the Mt. Simon in percent volume and areas of poor, fair, and good injection potential.

rate of 30 million gallons. Figure 8 compares the average monthly injection rates of each well for the years 1972 and 1984. Figure 9 compares the cumulative injected volumes for each well as of January, 1984.

These huge volumes of wastes are difficult to visualize, but, to diminish these volumes by comparing them to the pore space capacity of a reservoir, (as R. D. Ross did in Industrial Waste Disposal), can give the false impression that a reservoir is without limits. It can be demonstrated theoretically that the cumulative volume of 125,848,942 gallons injected at the Armco well No.# 1 can be contained within a radius of 542 feet from the well. The calculation is based on the following formula for the volume of a cylinder:

$$r = \frac{V}{7.48 \, \pi \, h \, \phi \, (1 - Sw)}$$

where

V = Volume of injected fluid (125,848,942 gallons).
r = Radius of influence.
7.48 = Number of gallons per cubic foot.
ϕ = Average porosity (0.13).
Sw = Irreducible water saturation (0.30).
π = 3.14
h = Thickness of porous formation (200').

Arthur Piper in Disposal of Liquid Wastes by Injection Underground- Neither Myth nor Millennium, notes that the area the waste occupies is actually achieved by compression of the native brine fluid and the injected waste, compression of the rock matrix within the Mt. Simon, and dilation of pore space. These factors oppose to the calculations based on the assumption that the waste will simply occupy available pore space, tend to decrease the volume of waste that actually occupies the calculated 542 ft. radius by 2 orders of magnitude.

Since liquids and rocks are not very compressable, the

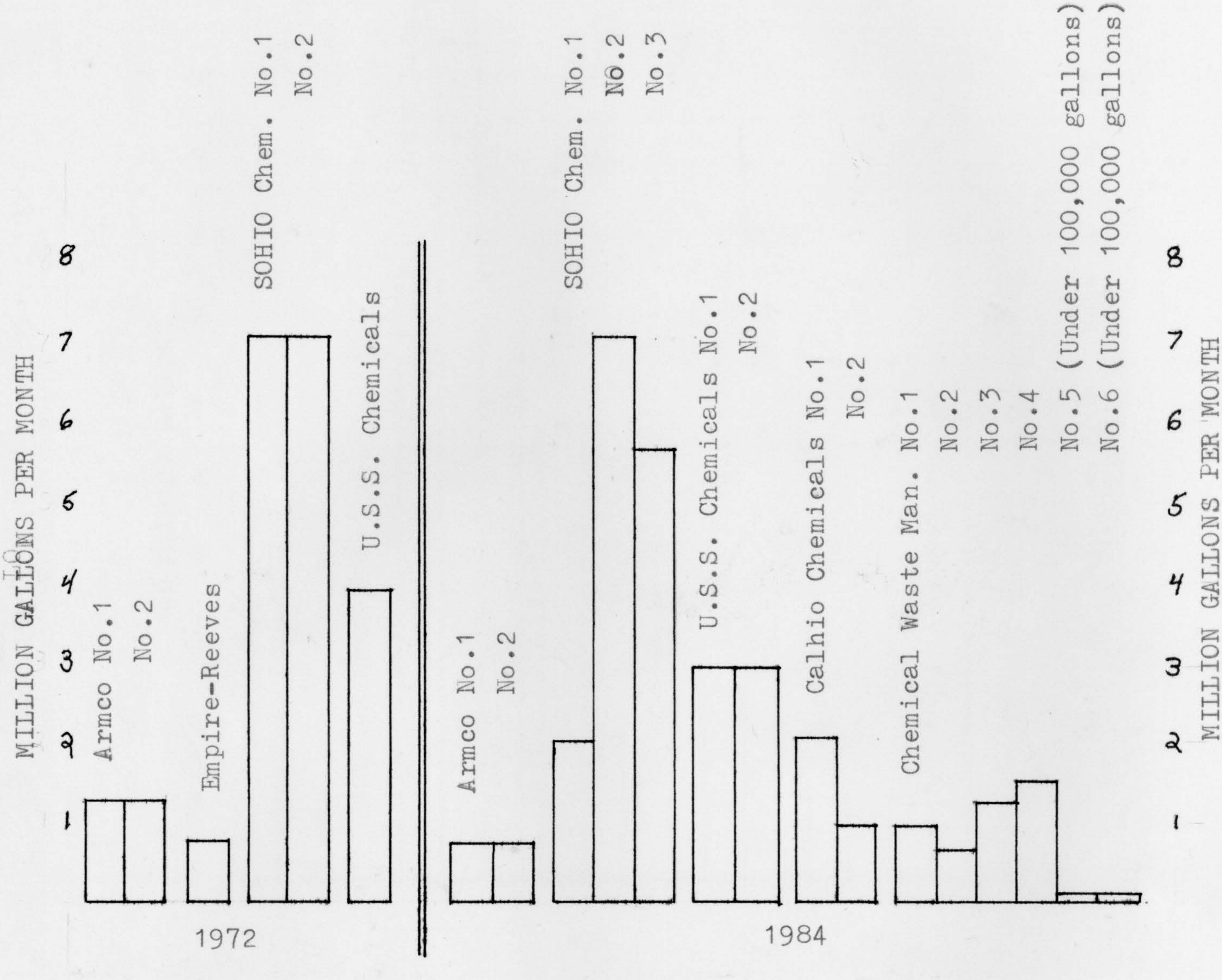

Figure 8. Average monthly injected volumes as of January, 1972 and for the year 1984.

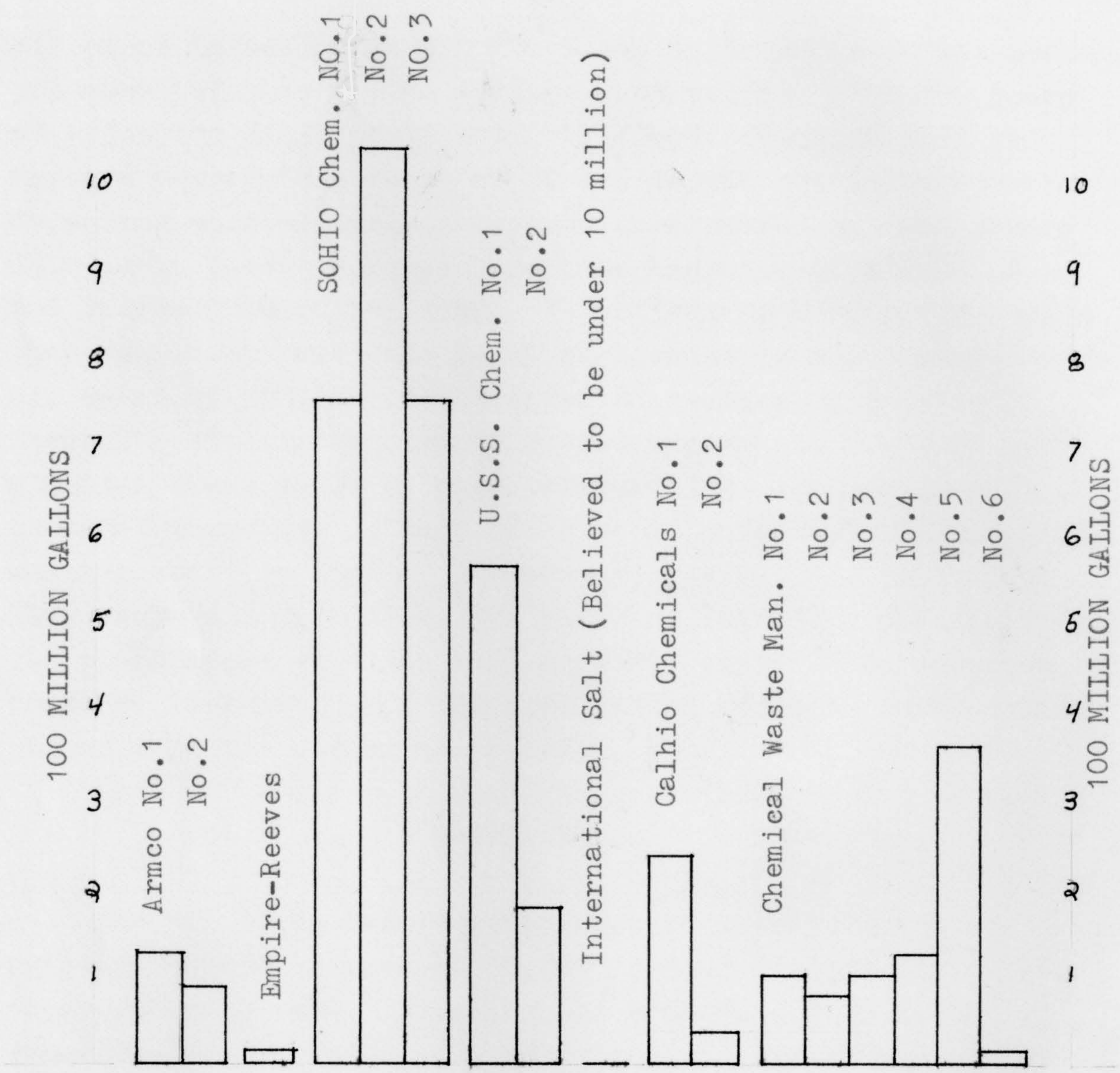

Figure 9. Cumulative volumes of injected industrial wastes in Ohio as of January, 1984.

effect of injection on the Mt. Simon is to increase its normal pressure which is on the average 0.51 psi/ft. For 100 years of injection at the 1972 rate, Clifford estimated that an average pressure increase of 50 psi to 100 psi would occur depending on the degree of liquid compression to pore space dilation. These pressures would be higher near the wells and decrease away from them. The effect of a 50 psi pressure increase would raise the level of liquids in any unplugged oil wells by 100 feet. The rates of vertical migration through confining beds would also increase and could be substantial along zones of high permeability. In addition, pressure increases on this scale could possibly initiate seismic activity, though the possibility of this occurring in Ohio is remote. Because, the rates of injection have increased 1.5 times since 1972 and will probably continue to increase, pressure increases in a 100 year period could be substantialy higher than the estimated 50 psi.

CONFINING BEDS

The Mt. Simon Sandstone in Ohio is overlaid with at least 2,000 and as much as 10,000 feet of "relatively impermeable" strata, isolating the sandstone from fresh water aquifers. The confining beds lying directly over the Mt. Simon in eastern Ohio are the Rome and Conasauga Formations, which grade into the Eau Claire Formation to the west. Janssens found that the Eau Claire Formation varies from a glauconitic siltstone to a very fine-grained sandstone interbedded with shales. Its thickness ranges from 200 to 562 feet. The Rome Formation overlying the Mt. Simon to the east is a very fine- to coarse- grained, oolitic , pettetal, sandy dolomite. Its thickness ranges from 190 to 715 feet. The Conasauga Formation overlying the Rome, consists of shales, glauconitic siltstone, very fine- grained sandstone, and limestone. The Conasauga's thickness varies regionally from 40 to 439 feet. Appendix A contains isopach maps of these three formations.

contains isopach maps of these three confining formations.

The relative nature of the "impermeability" of confining beds, and their limited ability to uniformly impede vertical migration of fluids, can be demonstrated by the variability of their permeability measurements. Clifford calculated for the Eau Claire Formation, a range of vertical migration rates of .05 gallons a day per feet^2 to 1950 gallons a day per feet^2 could result from injection into the Mt. Simon. The discordant nature of many of the formations overlying the Mt. Simon make the term "relatively impermeable" relatively impudent. However, the presence of thick sequences of shales, such as those in the Ordovician system, make the vertical migration rates for fluids successfully injected under them sufficiently slow.

ENVIRONMENTAL CONSIDERATIONS

A potential route for rapid vertical migration of the injected wastes, or, of the brines in the formation that they displace, is through old oil wells. In Ohio there have been an estimated 120,000 to 200,000 oil wells drilled since 1860. Many of these wells were not plugged and many more have been plugged inadequately. These wells allow fluids that reach them an unimpeded vertical flow. Determining if wells have been properly plugged can be difficult or impossible. Also, the locations of large numbers of wells are unknown. The fact that only an estimated 140 wells have penitrated the Mt. Simon is an adequate reason for limiting injection solely to this formation. An Oil and gas field map for Ohio showing the areas that have the greatest amount of these old wells is shown in Figure 10.

The velocity that a fluid can travel within the Mt. Simon under its natural pressure gradient is less than 7 in. a year. These horizonal gradient flows are insignificant in most areas. Nevertheless, a potential injection site must be

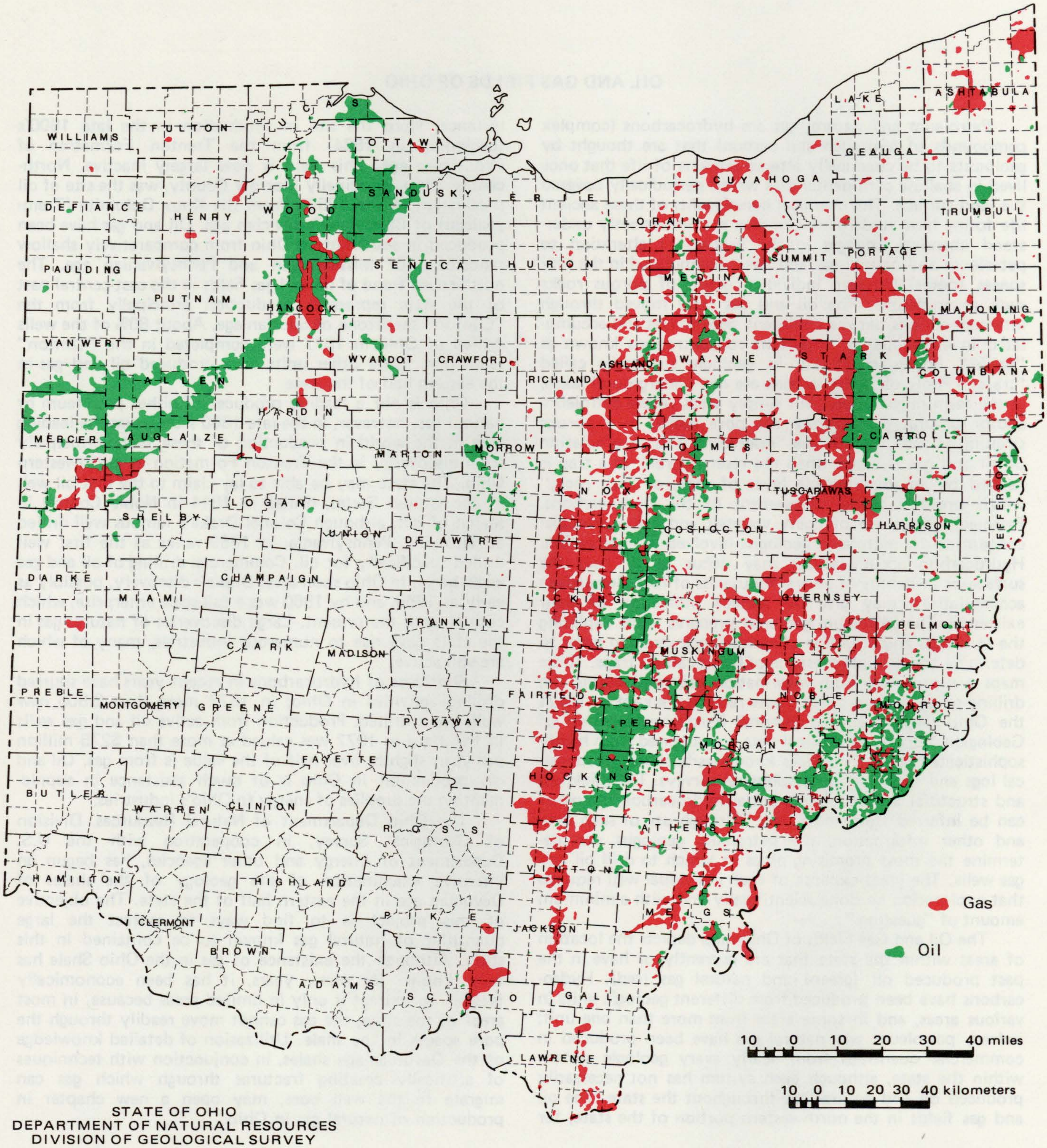

Figure 10.

OIL AND GAS FIELDS OF OHIO

Areas in which oil or gas is being produced or has been produced commercially since 1860.

A detailed version of this map, at a scale of 1 inch = about 8 miles, also is available. This more detailed map provides data on discovery date, depth, and producing horizon of individual pools, and stratigraphy. Natural gas and liquid petroleum storage areas in Ohio also are shown.

OIL AND GAS FIELDS OF OHIO

Petroleum and natural gas are hydrocarbons (complex compounds of hydrogen and carbon) that are thought by geologists to be chemically altered remains of life that once lived in shallow continental seas which periodically covered the land surface. The chemical constituents of these ancient life forms have undergone complex and imperfectly understood chemical changes in the process of alteration to petroleum and natural gas and have accumulated in the tiny spaces (pores) between individual grains of porous rocks such as sandstone. The oil and gas later moved through interconnections between adjacent pore spaces and accumulated in economically important concentrations known as "pools." Pools accumulate in geologic structures called "traps." Pools of hydrocarbons are not underground lakes, as the term might imply, but simply areas where petroleum and/or natural gas saturate the pore spaces in a porous stratum of rock, termed the "reservoir." The accumulation of oil and gas is aided when the reservoir rock in a trap is capped by an impermeable layer of rock, or "cap rock," which prevents further movement of the hydrocarbons. Petroleum traps are of many varieties and are a principal concern of the petroleum geologist involved in exploration. Hydrocarbon accumulations may occur at or near the surface or at depths of several thousands of feet. Subsurface accumulations may give no surface indication of their existence. The petroleum geologist prepares maps depicting the thickness and structure of various rock strata in order to determine the possible presence of hydrocarbon traps. These maps are prepared from information recorded during the drilling of oil and gas wells. These records are kept on file at the Ohio Department of Natural Resources, Division of Geological Survey. Additional data are obtained from highly sophisticated research devices known as borehole geophysical logs and from surface geophysical surveys. The thickness and structural attitude of potential hydrocarbon reservoirs can be inferred from these data. Through use of such data and other information, the petroleum geologist can determine the most promising areas in which to drill oil and gas wells. The great expense of each individual well requires that exploration be done scientifically and with a minimum amount of "guessing."

The Oil and Gas Fields of Ohio map depicts the location of areas within the state that are currently or have in the past produced oil (green) and natural gas (red). Hydrocarbons have been produced from different geologic units in various areas, and in some areas from more than one unit; indeed, petroleum and natural gas have been produced in commercial quantities from nearly every geologic system within the state, although each system has not necessarily produced oil and natural gas throughout the state. The oil and gas fields in the northwestern portion of the state, for instance, were the site of production in the late 1800's (beginning in 1884) from the Trenton Formation of Ordovician age. This field is now largely inactive. North-central Ohio, principally Morrow County, was the site of oil production in the 1960's from the Knox Dolomite (Trempealeau) of Cambrian-Ordovician age. Oil and gas have been produced in southeastern Ohio from comparatively shallow sandstones of Mississippian and Pennsylvanian age. The north-south trend of oil and gas fields in the east-central part of the state represents production principally from the "Clinton" sandstone of Silurian age. About 80% of the wells drilled in Ohio in 1977 were completed in the "Clinton" sandstone. Many other units have produced oil and gas in the eastern half of the state.

Ohio is not a leading producer of either petroleum or natural gas; however, in the late 1800's Ohio was the leading area in the world in production of these fuels, principally from discoveries in the Trenton Formation in northwestern Ohio. The state may be able to lay claim to the first oil well in the United States, drilled in 1814 in Noble County in search of salt, although Colonel Drake's famous well drilled at Titusville, Pennsylvania, in 1859 ranks as the first well drilled specifically for oil. Commercial drilling of oil and gas wells began in Ohio soon after Drake's discovery, possibly as early as 1859, and by 1860 was a full-scale enterprise, which continues to the present. Large discoveries of natural gas in the state gave rise to numerous industries, many of which are still active.

Shortages of hydrocarbons in recent years have spurred drilling activities in Ohio; in 1977 more than 2,500 new wells were drilled. Production from active oil and gas wells in the state in 1977 was valued at more than $275 million per year; slightly over half of the value is from gas. Oil and gas production in Ohio is of much assistance in supplementing the supplies of energy to Ohio's industries.

The Ohio Department of Natural Resources, Division of Geological Survey, in cooperation with the U.S. Department of Energy and other agencies, has begun an intensive examination of the geology of the shales of Devonian age in the eastern half of the state. The objective of this project is to find ways to extract the large quantities of natural gas known to be contained in this shale. Although the existence of gas in the Ohio Shale has been known for many years, it has been economically feasible to extract it only in limited areas because, in most areas of the state, the gas cannot move readily through the pore spaces in the shale. Utilization of detailed knowledge of the Devonian-age shales, in conjunction with techniques of artifically creating fractures through which gas can migrate to the well bore, may open a new chapter in production of natural gas in Ohio.

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thoroughly inspected for old oil wells to minimize their chances of contact with injected wastes.

The operation of injection wells at pressures exceeding the limits calculated from the break down pressure introduce several undesirable conditions. Excessive pressure could cause the Mt. Simon and its confining beds to fracture. These fractures have the ability to transmit wastes great distances vertically out of the injection zone and through the confining beds. High pressure can also cause well leaks by damaging the well equipment. The possibility of initiating seismic activity also increases as reservoir pressure increases.

Seismic activity can be produced from deep-wells where fluids are injected into zones of accumulated stress along shear planes. This was demonstrated at the Rocky Mountain Arsenal near Denver, where a well operating in the early 1960's caused several tremors. This seismic activity allows for a possible increase in permeability of affected formations, depending on the extent and development of the shear zone. The injection well equipment can also be damaged. The existence of deep faults in Ohio is not probable due to the simple structure of the basement rock and the sparse seismic activity, but, activity that has occurred probably indicates that some stress is accumulating. Possible micro-seismic activity induced by deep-well injection in Ohio has not been recorded and no tremors at these sites have been reported.

The greatest immediate risks that deep-well injection poses to the environment is through mismanagement. An example occurred at Empire-Revees who, in 1967 put Ohio's first deep-well into operation. Their well from installation until it was plugged in 1971, experienced extensive corrosion problems. The well's construction was not adequate and little concern was given for its safe operation. The well was plugged before a study could be made to determine the extent of the leakage, but, the Newburg Formation of Silurian age was believed to have been injected with an undetermined amount of waste. There have also been questions raised about the manner inwhich the well was plugged.

A personal interview with Jerry Myers of the Ohio E.P.A. revield another more recent case which occurred in the early 1980's. Durring this period all six wells at the Chemical Waste Management facility developed leakes that injected a total 40 million gallons of wastes into the Maynardville Formation (a Conasauga and Kerbal Formation equivalent). These leaks occurred because corrosion of the well casings went unchecked and, in the absence of shut off devices, improper monitoring of the equipment. For Chemical Waste Managements improper management and for their improper handling of the wastes at the surface, they have paid a total of 10 million dollars in fines to the Ohio E.P.A. and 2.5 million dollars to the Federal E.P.A. In addition to the fines, all of their wells had to be worked over at a substantial cost. Chemical Waste Management's total investment in their Ohio facility is 25 million dollars, excluding fines. Because of this disposal company's size thet have been able to absorb the loss and continue operating in Ohio.

UNDERGROUND INJECTION CONTROL

Recongnizing the need to properly regulate the use of deep-wells, federal legislators enacted The Safe Drinking Water Act in 1974. This established guidelines for state programs to license and inspect deep-wells. From this legislation the Ohio E.P.A. formed the state's Underground Injection Control Program (U.I.C.). This program officially takes regulatory control of deep-well injection on July 18, 1985. Previously all licenses were issued under the National Pollution Discharge Elimination System. Under this system permit applications had to be approved by the Ohio Department of Natural Resources Division of Geological Survey and Division of Oil and Gas, along with the Department of Health, and The Water Pollution

Control Board. Of these agencies only the two Divisions of the Ohio Department of Natural Resources had any expertise in this field and none of the agencies had much authority.

Crepeau explained that under the U.I.C. Program the primary regulatory agency is the Ohio E.P.A. Applications are now reviewed by the Ohio E.P.A. and the two previously mentioned Divisions of the Department of Natural Resources. If the permit application under review is in a coal-bearing district then the approval of the Division of Mines is also needed. Any of these agencies can deny the issuance of a license. For a company to put a deep-well into operation permits to drill and operate are necessary. Application forms to drill and operate are included in appendix B & C. Both applications require a substantial amount of information concerning geological, hydrological, and geophysical data. Lab analysis of the waste and the composition of the intended zone of injection are also needed. In addition, managerial plans, constructional procedures, and equipment lists are required.

The evaluations of the behavior of the wastes within the formation are left for the industries themselves to determine. Industries who don't properly evaluate the compatibility of their wastes with the reservoir stand to lose their well from a decrease in permeability that could occur from precipitation of the wastes or other unfavorable reactions. Though this information is not required, a centralized file of the waste's characteristics and its projected behavior would be more appropriate.

All wells that are already in operation must re-apply for a new operational permit under the U.I.C. Program by July 18, 1985. As of May 17 none of these applications had been received. Under these new guidelines an applicant must post a notice in the local newspaper for a 30 day period to allow public comment prior to permit approval. At this time a public hearing can be requested. This is an important stipulation because it increases the awareness of the disposal practice, whose extent of use or misuse the public may play a part in limiting.

The only new applicant to apply under the U.I.C. Program is Reserve Environmental Service. Jack Gray of the Ohio Geological Survey explained, the public notice period has expired without a public hearing and the operation permit is in the process of being approved (see Figures 1 and 2 for location and waste type). This site will operate 2 wells and will be located where the waste is generated. Because of the limited porosity and permeability of the Mt. Simon in this area and the volume of waste to be injected, these wells will be permittedto inject into the Rome and Conasauga Formations in addition to the Mt. Simon. This is the first permit to allow injection into formations other than the Mt. Simon.

The increased usage of other formations in areas of both poor and good injection potential will increase as the volumes of waste increase. With the approval of Reserve Environmental Services extended zone of injection, the Ohio E.P.A. in the future may find their decisions to limit other industries to the Mt. Simon, challenged. The Ohio E.P.A., in the past, has experienced the reversal of its regulatory decisions in the courts.

Because of the low cost of operating a deep-well (50,000 dollars annually after a 1 million dollar construction investment) as compared to other disposal and treatment techniques, no incentive exists for developing more feasible methods of treatment. Presently there are methods of treating many types of industrial wastes but few are economically feasible. These treatment methods would be preferred environmentally because they are capable of converting the wastes into innocuous forms suitable for disposal by uncontrolled methods or even for reuse. As long as the only limiting criteria for a well's injection rate are the nature of the reservoir and the break down pressure, feasible treatment techniques will be slower in development. It is for this reason and several others, the regulatory agencies should set volume limits on the rates of injection by industry, especially on the industries injecting wastes that have the greatest potential for treatment, i.e. nonhazardous. A possible ceiling at the present rates may move industries in the future toward treatment.

CONCLUSION

In the future, regardless of the possibility of volume limits, the amount of subsurface environment used to store industrial wastes in Ohio will increase. The rate of the increase will be determined largely by industries needs and the ability of the injection wells to avoid damaging headlines. Without conclusive studies detailing the long term effects of deep-well injection, regulatory agencies will continue to lack the needed guidelines and authority for a proper long term regulatory policy. At best, these agencies can continue to safeguard a limited resource from unecessary exploitation by issuing permits only to industries demonstrating a need. In comparison, the immediate risks that deep-well injection poses to the environment are conclusive, as evidenced by the failure of seven of Ohio's seventeen deep-wells. These immediate risks and uncertainty of long term effects, are sufficient reasons to limit this disposal practice as much as possible. Furthermore, if these immediate environmental risks remain high from continued well failures, then the risks of operating deep-wells in Ohio may outweigh their immediate benefits.

REFERENCES CITED

Carey, Robert. Engineer, Ohio E.P.A. Division of Solid and Hazardous Waste. Personal Interview at Columbus Office. May 1985.

Clifford, Michael J. Feasibility of Deep-well Injection of Industrial Liquid Wastes in Ohio. M.S. Thesis: Ohio State University, 1972. pp. 87.

Crepeau, Thomas E. Manager, Ohio E.P.A. Data Management Section Division of Solid and Hazardous Waste. Personal Interview at Columbus Office. May 1985.

Gray, Jack. Department Head, Ohio Geological Survey Sub-surface Section. Personal Interview at Columbus Office. May 1985.

Jannsens, A. Stratigraphy of The Cambrian and Lower Ord-ovician Rocks in Ohio. Ohio Geol. Survey Bulletin 64, 1973. pp. 197.

Myers, Jerry. Cordinator, Ohio E.P.A. Underground Injection Control Program. Personal Interview at Columbus Office. May 1985.

Ohio E.P.A. Underground Injection Control Program for Class I, IV, and V Wells. Memo, pp. 72.

Piper, Aurther M. Disposal of Wastes Underground- Neither Myth nor Millenium. U.S. Geol. Survey Circ. 631, 1969. pp. 12.

Sharp, D., Smail, H., et. al. State of Ohio Hazardous Waste Management Plan. Battelle Columbus Laboratories Report to Ohio E.P.A. December, 1978. pp. 167.

Warner, Don, L. "Deep-well Injection." From Industrial Waste Disposal. Ed. R.D. Ross. Conshohocken, PA.: Thermal Research and Engineering Corp., 1968. pp. 12.

APPENDIX A

Isopach maps of the Rome, Conasauga, and Eau Claire Formations for Ohio.

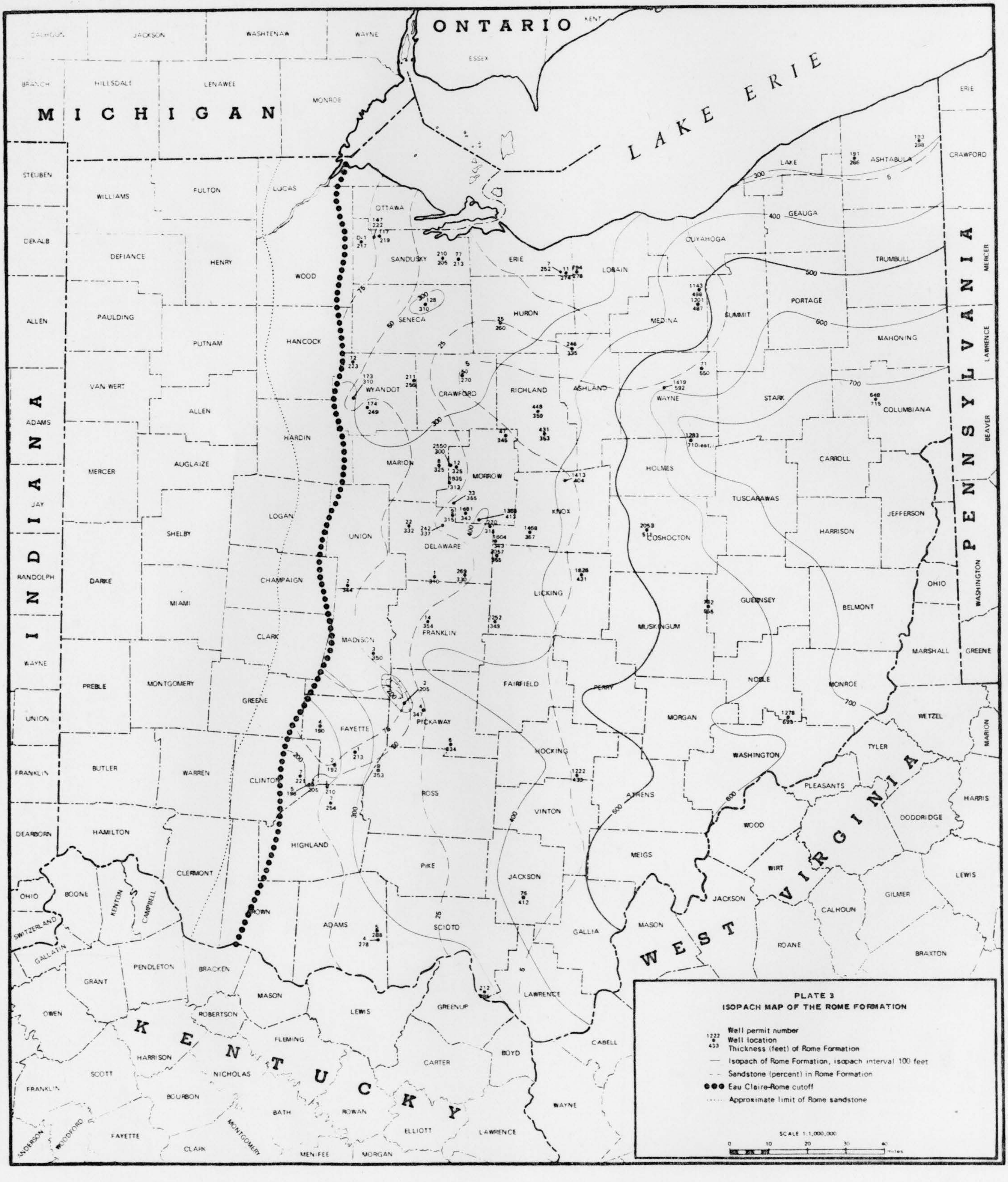
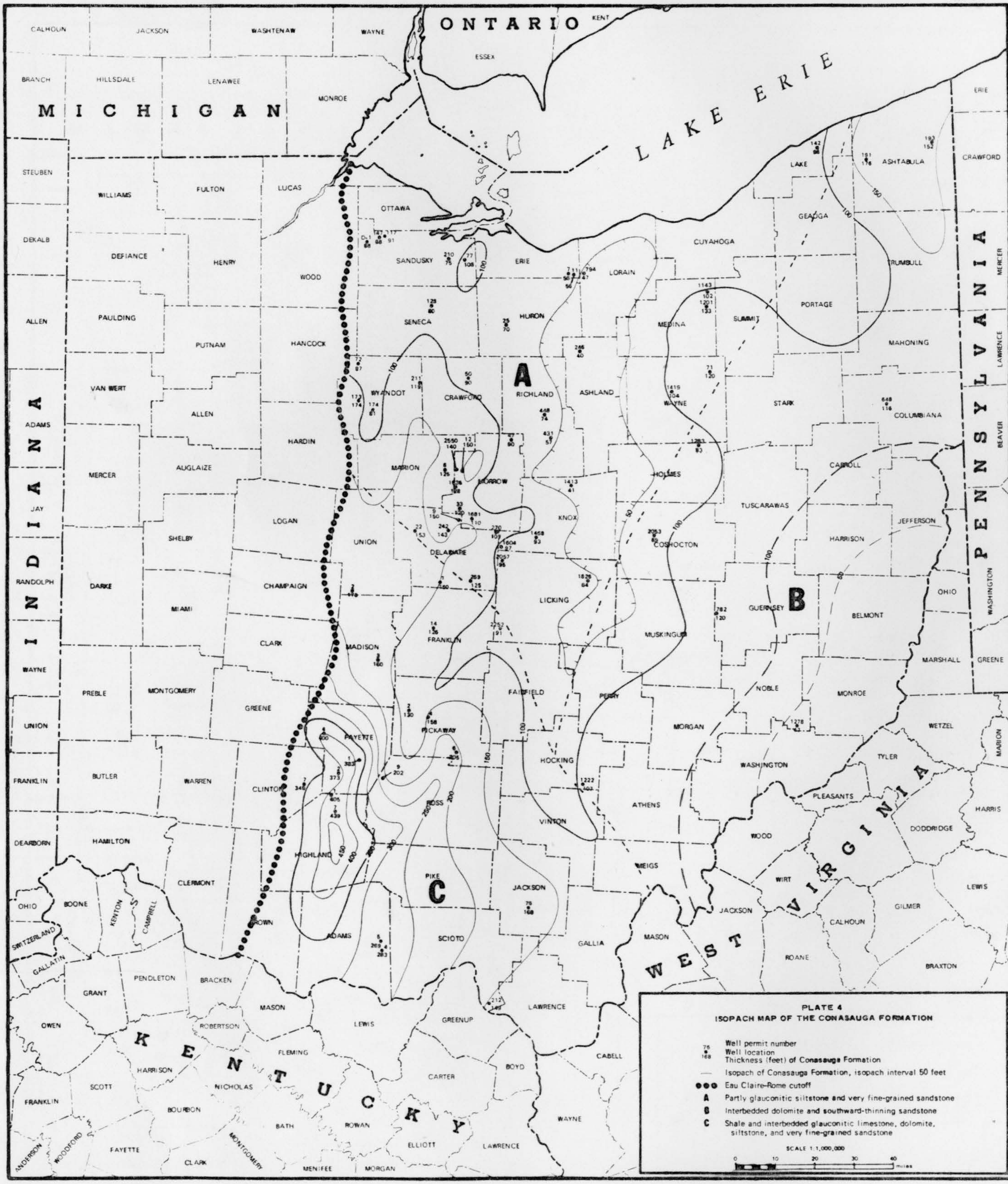


PLATE 3
ISOPACH MAP OF THE ROME FORMATION
Well permit number
Well location
Thickness (feet) of Rome Formation
Isopach of Rome Formation, isopach interval 100 feet
Sandstone (percent) in Rome Formation
Eau Claire-Rome cutoff
Approximate limit of Rome sandstone
SCALE 1:1,000,000
0 10 20 30 40 miles
ONTARIO
LAKE ERIE
MICHIGAN
INDIANA
PENNSYLVANIA
WEST VIRGINIA
KENTUCKY


ONTARIO
LAKE ERIE
MICHIGAN
INDIANA
PENNSYLVANIA
WEST VIRGINIA
KENTUCKY
A
B
C
PLATE 4
ISOPACH MAP OF THE CONASAUGA FORMATION
76 Well permit number
• Well location
168 Thickness (feet) of Conasauga Formation
Isopach of Conasauga Formation, isopach interval 50 feet
Eau Claire-Rome cutoff
A Partly glauconitic siltstone and very fine-grained sandstone
B Interbedded dolomite and southward-thinning sandstone
C Shale and interbedded glauconitic limestone, dolomite, siltstone, and very fine-grained sandstone
SCALE 1:1,000,000
0 10 20 30 40 miles

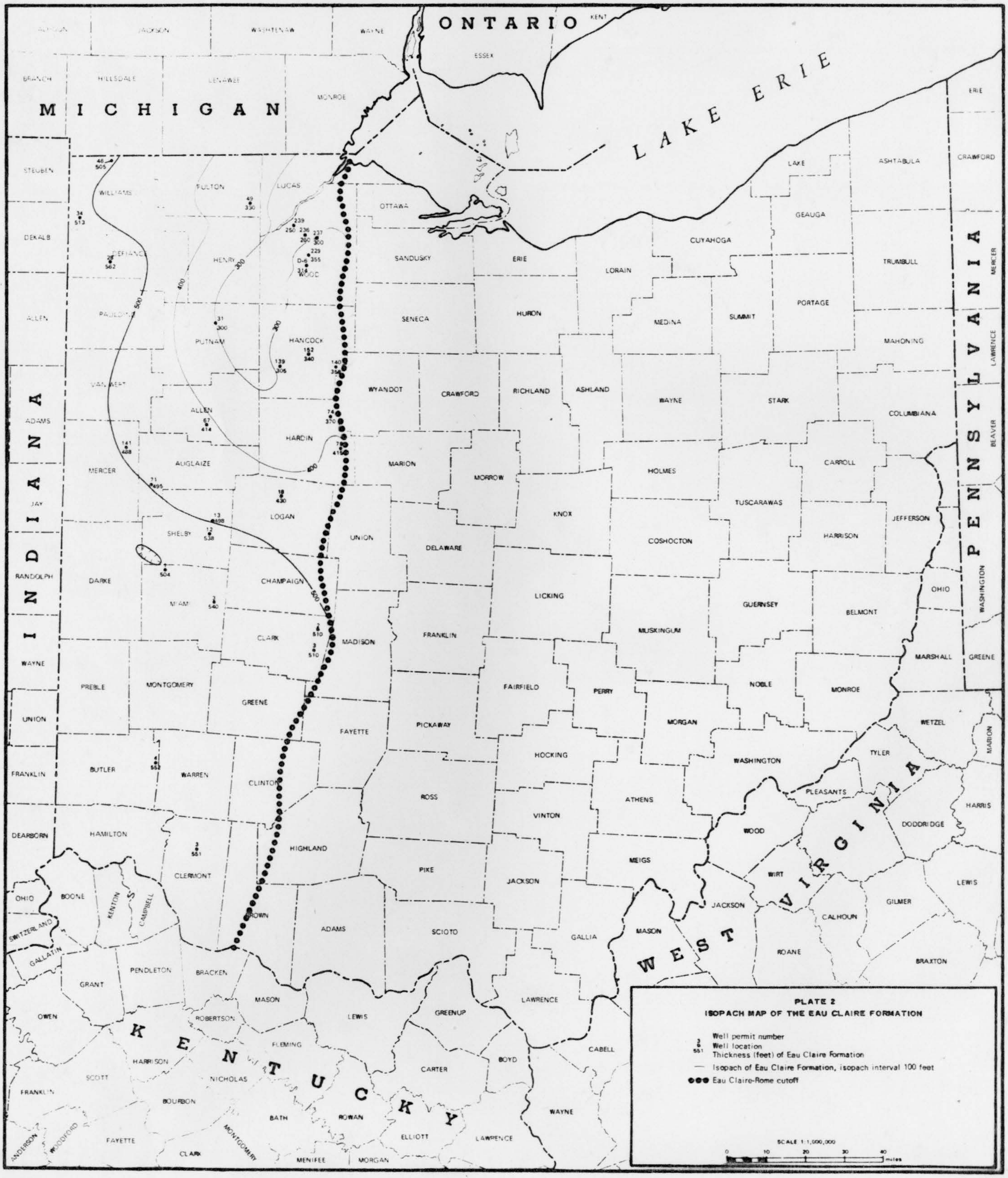


PLATE 2
ISOPACH MAP OF THE EAU CLAIRE FORMATION
Well permit number
Well location
Thickness (feet) of Eau Claire Formation
Isopach of Eau Claire Formation, isopach interval 100 feet
Eau Claire-Rome cutoff
SCALE 1:1,000,000
miles
ONTARIO
LAKE ERIE
MICHIGAN
INDIANA
PENNSYLVANIA
WEST VIRGINIA
KENTUCKY

APPENDIX B

Application for permit to drill.

OhioEPA

For Office Use Only
PTD Application No. ______________
Fee ______________

DIVISION OF SOLID & HAZARDOUS WASTE MANAGEMENT
UNDERGROUND INJECTION CONTROL PROGRAM
APPLICATION FOR PERMIT TO DRILL (Class I Wells)

____
Facility Name Primary Sic Code

____
Person to Contact

____
Facility Address

____
Mailing Address

____
City State Zip

____
City State Zip

Area Number ______________________________
Telephone

Area Number ______________________________
Telephone

/ / Federal / / State / / Private / / Public / / Other
Entity Status (check one)

Yes / / No / /
Is Facility on Indian Land?

____
If Corporation, Name and Address of Statutory Agent

____
Location of Well, including: Section or Lot Number, City/Village, Township and County

____
Well Number, Well Name

I, being the individual specified in Rule 3745-34-17 of the Ohio Administrative Code (OAC), hereby apply for a Permit to Drill the Underground Injection Well described herein.

____
Authorized Signature
(Pursuant to OAC Rule 3745-34-17)

____
Title

____
Date

Please be advised that this application must be accompanied by a non-refundable fee of $2000.00 pursuant to OAC Rule 3745-34-16(G)(1).

Please note: Construction of an injection well without an effective Underground Injection Control Permit to Drill is prohibited pursuant to Ohio Revised Code Sec. 6111.044.

0685R

EPA 9021

DIVISION OF SOLID & HAZARDOUS WASTE MANAGEMENT

INSTRUCTIONS AND PROCEDURAL INFORMATION

FOR FILING AN APPLICATION FOR A

UIC PERMIT TO DRILL

I. No person (individual, corporation, or other legal entity) may drill a well to investigate the acceptability of a site for disposal of liquid wastes without first obtaining a Permit to Drill from the Director, Ohio EPA.

II. The applicant shall submit: (1) an original permit application plus four copies; and (2) a check in the amount of $2,000.00 made payable to "Treasurer, State of Ohio".

All submittals are to be sent to:

Ohio EPA
Division of Solid & Hazardous Waste Management
Attn: Data Management Section
P.O. Box 1049
Columbus, OH 43216-1049

Telephone inquiries: (614) 466-8934 Bob Carey, UIC Coordinator

The main office of the Ohio EPA is located at 361 East Broad St., Columbus, Ohio.

III. Signature on application: Please refer to Rule 3745-34-17 of the Ohio Administrative Code, as attached.

IV. An application will not be processed until all information required to properly consider the application has been received. If an applicant fails to submit additionally requested information in a timely manner, the application may be returned.

Please note: Applicants shall keep records of all data used to complete permit applications and any supplemental information submitted for a period of at least 3 years from the date the application is signed. Please refer to Rule 3745-34-16(F) of the Ohio Administrative Code.

V. An applicant who is applying to dispose of hazardous waste shall also submit a RCRA Part A and Part B application. The Part A application form is available from the Ohio EPA, Division of Solid & Hazardous Waste Management, Data Management Section.

VI. The Permit to Drill application will be reviewed by the Ohio Department of Natural Resources, Division of Oil & Gas, and the Division of Geological Survey; the Ohio Department of Industrial Relations, Division of Mines; and the Ohio EPA, Division of Solid & Hazardous Waste Management.

VII. The applicant will be notified in writing of the decision of the Director of the Ohio EPA.

For Office Use Only
PTD Application No. ____________

DIVISION OF SOLID & HAZARDOUS WASTE MANAGEMENT
UIC PERMIT TO DRILL APPLICATION

APPENDIX (Class I Wells)

N.B. Please provide the information requested on this Appendix or on separate sheets of paper as indicated.

1. Well No. ____ Well Depth ____ Elevation of Well ____ (GL)
2. Max. Inj. Rate ____ (GPM) Avg. Inj. Rate ____ (GPM) Max. Surf. Inj. Pres. ____ (PSIG)
3. Name and Depth of Injection Zone ____ KB to Ground Level ____
4. Provide a brief description of the nature of your firm's business.

5. Describe activities conducted by the applicant which require that permits be obtained under the following environmental programs as applicable:

   a) Resource Conservation & Recovery Act (RCRA);

   b) Underground Injection Control Program (UIC);

   c) The National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act, and Chapter 6111. of the Ohio Revised Code;* and

   d) The Prevention of Significant Deterioration Program (PSD) under the Clean Air Act and Chapter 3704. of the Ohio Revised Code.

6. Provide a listing of all permits or construction approvals received or applied for under any of the following programs:

   a) Hazardous Waste Management Program under RCRA and Chapter 3734. of the Ohio Revised Code;

   b) UIC Program under the Safe Drinking Water Act (SDWA) and Chapter 6111. of the Ohio Revised Code;

   c) NPDES Program under the Clean Water Act (CWA) and Chapter 6111. of the Ohio Revised Code;

   d) Prevention of Significant Deterioration Program (PSD) under the Clean Air Act and Chapter 3704. of the Ohio Revised Code;

   e) Nonattainment Program under the Clean Air Act and Chapter 3704. of the Ohio Revised Code;

   f) National Emission Standards for Hazardous Pollutants (NESHAPS) preconstruction approval under the Clean Air Act and Chapter 3704. of the Ohio Revised Code;

*Please Note: If liquid or semi-liquid wastes are discharged to a POTW, provide the POTW NPDES permit number.

g) Ocean Dumping Permits under the Marine Protection Research and Sanctuaries Act;

h) Dredge and Fill Permits under Section 404 of the CWA and Chapter 3745-32 of the Ohio Administrative Code; and

i) Other relevant environmental permits, including state permits.

7. Provide a topographical map (or other map if a topographical map is unavailable) on a scale not smaller than four hundred feet to the inch, prepared by an Ohio registered surveyor, extending one mile beyond the property boundaries of the source depicting the facility and each of its intake and discharge; each of its hazardous waste treatment, storage or disposal facilities, including but not limited to neutralization ponds, segregating or mixing tanks, and any solid waste disposal areas on site; each well where fluids from the facility are injected underground, including but not limited to known mines, mineral deposits, and other oil and gas reserves; and those wells, springs, and other surface water bodies, and drinking water wells listed in public records or otherwise known to the applicant within a quarter mile of the facility property boundary. If the well is or is to be located within the excavations and workings of a mine, the map shall also include the location of such mine, the name of the mine, and the name of the person operating the mine.

8. Describe the type of drilling equipment to be used.

9. Provide a plan for the disposal of water and other waste substances resulting, obtained, or produced in connection with the injection process.

10. State the composition of the substance to be injected.

11. Submit with this application your plans for testing, drilling, and construction.

12. Identify the location of all known wells within the injection well's area of review which penetrate the injection zone. In addition, submit a plan of "corrective action" for all wells which are improperly sealed, completed, or abandoned and consisting of such steps or modifications as are necessary to prevent movement of fluid into underground sources of drinking water. The following criteria and factors are to be included in the plan of corrective action:

    a) Nature and volume of injected fluid;

    b) Nature of native fluids or by-products of injection;

    c) Potentially affected population;

    d) Geology;

    e) Hydrology;

    f) History of the injection operation;

    g) Completion and plugging records;

    h) Abandonment procedures in effect at the time the well was abandoned;

    i) Hydraulic connections with underground sources of drinking water; and

    j) surface waste handling operations.

13. Provide a map showing the injection well(s) for which a permit is sought and the applicable area of review. Within the area of review, the map must show the number or name, and location of:

    a) all producing wells;

    b) injection wells;

    c) abandoned wells;

    d) dry holes;

    e) surface bodies of water;

    f) springs;

    g) mines (surface and subsurface);

    h) quarries;

    i) water wells;

    j) other pertinent surface features including residences and roads; and

    k) faults, if known or suspected.

14. Provide a tabulation of data on all wells within the area of review which penetrate into the proposed injection zone. Such data shall include the following:

    a) description of each well's type;

    b) construction;

    c) date drilled;

    d) location;

    e) depth; and

    f) record of plugging and/or completion.

15. Provide maps and cross sections indicating the general vertical and lateral limits of all underground sources of drinking water within the area of review, their position relative to the injection formation and the direction of water movement, where known, in each underground source of drinking water which may be affected by the proposed injection.

16. Submit the method of determination of the proposed area of review pursuant to OAC Rule 3745-34-32.

17. Provide the following information as indicated:

a) maps and cross sections detailing the geologic structure of the local area;

b) generalized maps and cross sections illustrating the regional geologic setting; and

c) proposed operating data including:

i) average and maximum daily rate and volume of the fluid to be injected;

ii) average and maximum injection pressure; and

iii) source and analysis of the chemical, physical, radiological and biological characteristics of injection fluids.

d) proposed formation testing program to obtain an analysis of the chemical, physical and radiological characteristics of and other information on the receiving formation;

e) proposed stimulation program;

f) proposed injection procedure;

g) schematic or other appropriate drawings of the surface and subsurface construction details of the well;

h) contingency plans to cope with all shut-ins or well failures so as to prevent migration of fluids into any underground source of drinking water;

i) plans (including maps) for meeting the monitoring requirements in Paragraph (B) of Rule 3745-34-38 of the Administrative Code;

j) construction procedures including a cementing and casing program, logging procedures, deviation checks, and a drilling, testing and coring program. These procedures should address the factors in OAC Rule 3745-34-37(B), (C)(2) and (3), (D) and (E);

k) a certificate that the applicant has assured, through a performance bond or other appropriate means, the resources necessary to close, plug or abandon the well as required by paragraph (B)(6) of Rule 3745-34-27 of the Ohio Administrative Code;

l) location, including, but not limited to, seismic areas, wetlands, flood hazard areas, carbonate formations that result in caverns, and underground mines, both active and abandoned; and

m) the means to dispose of any sludges, solid wastes, or semi-solids or liquids generated in the treatment of any wastes received.

18. Drilling and construction shall be supervised by a qualified drilling engineer who has authority to act for the company on matters concerning drilling.

19. Casing testing must be witnessed by a qualified engineer.

20. Any core analyses, if performed, are to be analyzed for at least:

a) Permeability;

b) Porosity;

c) % saturation of each fluid;

d) Sample description;

e) Sieve analysis of sand; and

f) Compatibility testing of cores with waste stream for permeability reduction.

21. The completion report, submitted prior to operation, is to include:

A. Drilling and Completion Records:

1. Daily reports;
2. Driller's log or record of strata;
3. Casing and tubing records: pipetallys;
4. Detailed screen and liner setting;
5. Cementing records;
6. Details of centralizers, scratchers, and other such equipment; and
7. Engineering drawings of:

   a. well completion;
   b. packer assembly and setting; and
   c. well head, parts list.

B. Geophysical Logs:

1. Final prints of all logs run on well;
2. Interpretation of logs by qualified person; and
3. Directional or inclinational survey.

C. Testing Records:;

1. Well testing:

   a. static fluid level;
   b. bottom hole temperature and pressure;
   c. injectivity test results; permeability determination, reservoir limits, storage;
   d. spinner or tracer surveys; and
   e. casing testing results.

2. Lab testing:

   a. cores for permeability;
   b. cores for compatibility;
   c. cores for porosity;
   d. analysis of formation water;
   e. compatibility of waste and formation water; and
   f. descriptive core analysis and/or sieve analysis.

22. Injectivity testing must include pressure/time relationships to determine permeability, transmissivity, and reservoir limits, if any.

Completed by ______________________________

Title ______________________________

Date ______________________________

APPENDIX C

Application for permit to operate.

OhioEPA

For Office Use Only
PTO Application No. ______________
Fee ______________

DIVISION OF SOLID & HAZARDOUS WASTE MANAGEMENT
UNDERGROUND INJECTION CONTROL PROGRAM
APPLICATION FOR PERMIT TO OPERATE (Class I Wells)

Facility Name Primary Sic Code

Person to Contact

Facility Address

Mailing Address

City State Zip

City State Zip

Area Number
Telephone

Area Number
Telephone

/ / Federal / / State / / Private / / Public / / Other
Entity Status (check one)

Yes / / No / /
Is Facility on Indian Land?

If Corporation, Name and Address of Statutory Agent

Location of Well, including: Section or Lot Number, City/Village, Township and County

Well Number, Well Name

I, being the individual specified in Rule 3745-34-17 of the Ohio Administrative Code (OAC), hereby apply for a Permit to Operate the Underground Injection Well described herein.

Authorized Signature
(Pursuant to OAC Rule 3745-34-17)

Title

Date

Please be advised that this application must be accompanied by a non-refundable fee of $2000.00 pursuant to OAC Rule 3745-34-16(G)(1).

Please note: Operation of an injection well without an effective Underground Injection Control Permit to Operate is prohibited pursuant to Ohio Revised Code Sec. 6111.044.

OhioEPA

DIVISION OF SOLID & HAZARDOUS WASTE MANAGEMENT

INSTRUCTIONS AND PROCEDURAL INFORMATION

FOR FILING AN APPLICATION FOR A

UIC PERMIT TO OPERATE

I. No person (individual, corporation, or other legal entity) may begin operating a disposal well without first obtaining a Permit to Operate from the Director, Ohio EPA.

II. The applicant shall submit: (a) an original permit application plus four copies; and (b) proof of financial liability and mechanical integrity; and (c) a check in the amount of $2,000.00 made payable to "Treasurer, State of Ohio". All submittals are to be sent to:

Ohio EPA
Division of Solid & Hazardous Waste Management
Attn: Data Management Section
P.O. Box 1049
Columbus, OH 43216-1049

Telephone inquiries: (614) 466-8934 Bob Carey, UIC Coordinator

The main office of the Ohio EPA is located at 361 East Broad St., Columbus, Ohio.

III. Signature on application: Please refer to Rule 3745-34-17 of the Ohio Administrative Code.

IV. An application will not be processed until all information required to properly consider the application has been received. If an applicant fails to submit additionally requested information in a timely manner, the application may be returned.

V. The Permit to Operate application will be reviewed by the Ohio Department of Natural Resources, Division of Oil and Gas and the Division of Geological Survey; the Ohio Department of Industrial Relations, Division of Mines; and the Ohio EPA, Division of Solid & Hazardous Waste Management.

VI. The applicant will be notified in writing of the decision of the Director of the Ohio EPA.

OhioEPA

For Office Use Only
PTO Application No. ____________________

DIVISION OF SOLID & HAZARDOUS WASTE MANAGEMENT
UIC PERMIT TO OPERATE APPLICATION

APPENDIX (Class I Wells)

N.B. Please provide the information requested on this Appendix or on separate sheets of paper as indicated.

1. Well No. ________ Well Depth ________ Elevation of Well ________ (GL)
2. Max. Inj. Rate ____ (GPM) Avg. Inj. Rate ____ (GPM) Max. Surf. Inj. Pres. ____ (PSIG)
3. Name and Depth of Injection Zone ________ KB to Ground Level ________

4. Provide a brief description of the nature of your firm's business.

5. Describe activities conducted by the applicant which require that permits be obtained under the following environmental programs as applicable:

   a) Resource Conservation & Recovery Act (RCRA);

   b) Underground Injection Control Program (UIC);

   c) The National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act, and Chapter 6111. of the Ohio Revised Code;* and

   d) The Prevention of Significant Deterioration Program (PSD) under the Clean Air Act and Chapter 3704. of the Ohio Revised Code.

6. Provide a listing of all permits or construction approvals received or applied for under any of the following programs:

   a) Hazardous Waste Management Program under RCRA and Chapter 3734. of the Ohio Revised Code;

   b) UIC Program under the Safe Drinking Water Act (SDWA) and Chapter 6111. of the Ohio Revised Code;

   c) NPDES Program under the Clean Water Act (CWA) and Chapter 6111. of the Ohio Revised Code;

   d) Prevention of Significant Deterioration Program (PSD) under the Clean Air Act and Chapter 3704. of the Ohio Revised Code;

   e) Nonattainment Program under the Clean Air Act and Chapter 3704. of the Ohio Revised Code;

   f) National Emission Standards for Hazardous Pollutants (NESHAPS) preconstruction approval under the Clean Air Act and Chapter 3704. of the Ohio Revised Code;

*Please Note: If liquid or semi-liquid wastes are discharged to a POTW, provide the POTW NPDES permit number.

g) Ocean Dumping Permits under the Marine Protection Research and Sanctuaries Act;

h) Dredge and Fill Permits under Section 404 of the CWA and Chapter 3745-32 of the Ohio Administrative Code; and

i) Other relevant environmental permits, including state permits.

7. Provide a topographical map (or other map if a topographical map is unavailable) on a scale not smaller than four hundred feet to the inch, prepared by an Ohio registered surveyor, extending one mile beyond the property boundaries of the source depicting the facility and each of its intake and discharge; each of its hazardous waste treatment, storage or disposal facilities, including but not limited to neutralization ponds, segregating or mixing tanks, and any solid waste disposal areas on site; each well where fluids from the facility are injected underground, including but not limited to: known mines, mineral deposits, and other oil and gas reserves; and those wells, springs, and other surface water bodies, and drinking water wells listed in public records or otherwise known to the applicant within a quarter mile of the facility property boundary. If the well is or is to be located within the excavations and workings of a mine, the map shall also include the location of such mine, the name of the mine, and the name of the person operating the mine.

8. Describe the type of drilling equipment to be used.

9. Submit with this application a plan for plugging and abandonment pursuant to the provisions of OAC Rules 3745-34-36(A)-(C), 3745-34-37(B)(5), and 3745-34-39(C).

10. Submit evidence of financial responsibility including a surety bond, or other adequate assurance, such as financial statements, or other materials acceptable to the Director. For Class I hazardous injection wells, financial responsibility must be demonstrated pursuant to OAC Rule 3745-34-36(D).

11. Submit proof of mechanical integrity pursuant to OAC Rule 3745-34-34.

12. Summarize the following information:

Injection Zone

(a) Depth drilled;
(b) Lithostatic pressure gradient (Use 1.0 PSI/ft.);
(c) Fracture pressure (PSIG) (Show how derived);
(d) Average porosity;
(e) Permeability (millidarcies);
(f) Bottom hole temperature;
(g) Lithology;
(h) Bottom hole pressure (PSIG);
(i) Datum level KB ( ) GL ( ) MSL ( );
(j) Chemical characteristics of formation fluid, including complete chemical analysis;*

*Minimum analysis to include (provide reasons if any of the following are omitted):

silica	sulfate	total dissolved solids	cadmium
calcium	chloride	potassium	iron
magnesium	fluoride	manganese	pH
sodium	nitrate	barium	dissolved oxygen
carbonate	viscosity	boron	hydrocarbons
bicarbonate	conductivity	strontium	specific gravity
hydrogen sulfide	temperature		

(k) Depth to base of useable quality water (3000 mg/L TDS);
(l) Depth to base of potentially useable water (10,000 mg/L TDS); and
(m) Geologic description of aquifer units

(a) Name	(b) Age	(c) Depth	(d) Thickness	(e) Lithology	(f); TDS (Ave.)

13. Summarize the well design and construction as follows:

    (a) <u>Casing and tubing</u>

    (1) Surface casing - size, weight, grade, depth-GL
    (2) Intermediate casing - size, weight, grade, depth-GL
    (3) Long string casing - size, weight, grade, depth-GL
    (4) Injection tubing - size, weight, grade, depth-GL

    (b) <u>Cement data</u>

    (1) Surface casing - type/class, additives, amount, circulate
    (2) Long string - type/class, additives, amount, circulate
    (3) Other - type/class, additives, amount, circulate

    (c) <u>Packer</u>

    (1) Type
    (2) Name and model number
    (3) Setting depth
    (4) Type annular fluid used

    (d) <u>Bottom Hole Completion</u> (description).

14. Provide a chronology of all major workovers and well malfunctions, a brief description of reasons for the well failure, and the corrective actions taken.

15. Provide a sketch of the injection well showing casing, cement, tubing, packer, etc., with proper setting depths, including wellhead and gauges. (Refer to example included in application package).

16. Provide a summary of wells shown on the topographic map as follows:

    (a) Number of wells in the 2 1/2 mile area of review which are within 300 feet of the permitted injection interval and wells within a 1/2-mile radius of the injection well;

    (b) Number of wells in 16(a) above that are plugged and abandoned;

    (c) Number of wells inadequately plugged and abandoned or on which records are incomplete (include all available records with this application); and

    (d) Number of above wells that are still producing.

17. Provide a tabulation of data on all wells listed in No. 16 above. Include: operator, lessee or owner, distance from injection well, well number, casing size, setting depth and cementing data for surface, intermediate and long string casings, and plugging data for all abandoned wells.

18. Provide all available logging and testing data on the well for which this application applies.

19. Provide the anticipated maximum pressure and flow rate at which the permitee will operate the well.

20. Provide the results of the formation testing program.

21. Provide the actual injection pressure.

22. Provide an analysis of the compatibility of injected waste with fluids in the injection zone and minerals in both the injection zone and the confining zone.

23. Provide the status of corrective action on defective wells in the area of review.

Completed by ______________________________

Title ______________________________

Date ______________________________